REMARKS

In the office action, the examiner rejected independent claims 1 and 14, and all claims depending upon them, and dependent claim 17 as not enabled. Applicants respectfully disagree, and offer the following explanation. As the examiner observes, claim 1 speaks of "fluid flow between gridcells . . . and component transport rate between regions." Claim 17 has essentially the same passage. (The foregoing refers to the original claim wording.) Claim 14 states in part, "the mass transfer of each component between the regions." As the claims provide, each gridcell is divided into two regions, one swept by the injected fluid and the other unswept. The examiner notes that the specification states that the simulation model provides for fluid "flow" between gridcells but not between regions of a gridcell. The examiner then asks how can there be "transport" or "mass transfer" between regions of a gridcell if there can be no fluid flow between regions? The answer is that any person trained in the art understands that "flow" means something different than "component transport" or "mass transfer of components." "Flow" is a movement of fluid due to gradients in flow potential, i.e., pressure differences. Component "transport" or "mass transfer" refers to movement of mass due to other driving forces, e.g., differences in composition. As stated at lines 13-15 of page 19, the mixing processes accounted for by a mass transfer function include molecular diffusion, convective dispersion and capillary dispersion. The mass transfer function is discussed at pages 22-26. Thus, when reading on page 14, lines 26-27, "there are no inter-node connections between resident region 16 and invaded region 17," a person trained in the art would understand that that is equivalent to a statement that the flow potential is the same in the two regions, which says nothing about mass transfer. As stated in lines 21-22 (page 14), fluid "flow" is assumed to take place between gridcell nodes. The model assigns one node per gridcell (line 20). Yes, it follows that there is no "flow" between regions of the same gridcell, but not that there can be no "component transport" or "mass transfer" between regions. Attention is directed to (for example) page 2, lines 24-26; page 13, lines 13-15; and page 14, lines 2-3 ("Components are allowed to transfer in either direction across the partition 18."). See also the reference to "multi-component fluids" on line 7, page 13. These last cited passages explain the difference in terms the lay reader can understand. In any event, Applicants submit herewith a § 1.132 affidavit of a person skilled

in the reservoir simulation art (co-inventor Gary Teletzke), to the effect that the cited portions in the claims do not require undue experimentation, for the reasons stated above, and hence do not present an enablement problem.

Although "transport" and "mass transfer" are used interchangeably in the specification, the latter term has been selected for consistency purposes throughout the amended claims included herein.

In the office action, the examiner raises several antecedent basis issues, causing a rejection of all 18 original claims for indefiniteness. In every such instance, the antecedent basis has been clarified in the enclosed amended claims. It may help to realize that the terms "solvent," "injected fluid," and "displacement fluid" are used essentially interchangeably in the application, which would be readily recognized by a person of ordinary skill in the art.

In the office action, the examiner rejects claims 1-17 because they could be practiced with pencil and paper (and thus lack tangible embodiment removing them from the category of the technology arts, according to the examiner). The subject invention is a reservoir simulation method. As a practical matter, such an invention would be implemented as a software program and probably executed on a reasonably high-powered computer. (Page 18, lines 27-29) That would be a tangible embodiment. However, Applicants believe it is well settled that such claims do not have to be limited to use of a computer to carry out the method. Nevertheless, in order to expedite examination of this application, independent claims 1, 14 and 16 are amended herein to include the phrase "computer-implemented."

In the office action, the examiner rejects independent claims 1, 14, 16 and 18 as obvious over King in view of Meakin. (King is actually the editor of a compilation of papers; the reference the examiner has in mind is a paper by Fayers, et al., but we will continue to refer to it herein as "King" to minimize confusion.) As stated on page 7, lines 6-20 of the present application, various prior art models including those of King and Nghiem use empirical correlations to represent oil/solvent mobilities in each region and to represent component transfer between regions. (As requested by the examiner, a copy of the Nghiem

article is provided in a Supplementary Information Disclosure Statement enclosed herewith.) The correlation process involves running fine-grid simulations and fitting the empirical mobility and mass transfer functions to the fine-grid results. A fine-grid simulation of a petroleum reservoir is a very complex, time-consuming and expensive computer calculation. An inventive step of the present invention is that only a coarse grid is used. This is accomplished by putting fine-scale information into the coarse-grid calculation as analytical formulas, i.e., functional dependence. Moreover, the functional dependence improves on another limitation of the empirical approaches, namely that they are unlikely to predict accurately performance outside the parameter ranges explored in the reference fine-grid simulations. The functional dependence feature is disclosed in the present application beginning on line 9 of page 15. To emphasize this feature of the invention in the claims, the present claim amendments insert after "percolation theory" in the independent claims (1, 14, 16 and 18) the modifying phrase, "to provide fine-grid adverse mobility displacement behavior through functional dependencies." Support for these words is found on page 4, line 17 and page 15, line 15. The terms "fine-scale" and "fine-grid" are used interchangeably; see, for example, page 7, line 17. A fine-scale grid is defined on page 10, lines 18-22 of the present application. As stated in the following paragraph (p. 10, line 23 to p. 11, line 5), the direct use of fine-scale models for full-field reservoir simulation is generally not feasible because their fine level of detail places prohibitive demands on computational resources. A coarse-scale grid must be, and typically is, used. A critical feature that the present invention provides that the prior art such as King and Nghiem does not is the capability to represent accurately the physics of effects like fingering, channeling and mixing on a coarse grid, thus enabling more efficient prediction of adverse mobility displacement performance.

King clearly states that his method of dealing with fingering is to use empirical correlations, calibrated to the results of fine-grid simulations, to modify the flow terms in the component mass balance equations and to represent component transfer between regions (pages 116 and 134 through 142). King does not suggest specific functional forms for the modified flow terms and transfer function. Nghiem uses simple saturation weighting to modify liquid phase relative permeabilities (Equations 9 and 10 on page 421), uses an empirical viscosity mixing rule (Equation 13), and proposes an empirical two-parameter

transfer function (Equations 3, 11, 12, 18, and 19). Nghiem determines the parameters in the empirical transfer function by fitting them to experimental data and fine-grid simulations ("Preliminary Validation" section on pages 422-423).

The examiner correctly recognizes that King does not disclose or suggest modeling fluid flow between gridcells using principles of percolation theory. Neither does Nghiem. The examiner contends that Meakin teaches this step and that it would be obvious to combine the two references to arrive at the present invention. Applicants respectfully disagree. Meakin's article targets a different physical problem.

Meakin presents the results of exploratory numerical studies on one- and two-phase flow in fractures (Abstract, page 1), that are macroscopic breaks, ruptures, or cracks in a solid material. Although Meakin mentions that fractures may play a role in fluid flow in petroleum reservoirs, he describes methods for simulating two entirely different physical problems than the methods disclosed in the present application for representation of fine-grid adverse mobility displacement behavior in coarse-grid reservoir simulation models through functional dependencies. Section 2 of Meakin describes the use of a modified site invasion percolation model to numerically simulate the slow displacement of a wetting fluid from a fracture aperture by an invading non-wetting fluid. Invasion percolation is a form of percolation theory that refers to a method for modeling immiscible displacement at a constant but infinitesimal flow rate, such that viscous forces are completely dominated by the capillary forces acting at the fluid interfaces (Wilkinson, D., and Willemsen, J. F., "Invasion Percolation: A New Form of Percolation Theory," J. Phys. A: Math. Gen. **16** (1983) 3365-3376, paragraph 4 on page 3365). Because viscous forces are neglected, the methods of invasion percolation are not useful for modeling adverse mobility displacement, the mechanisms of which are dependent on differences in the viscous forces acting on the injected and resident fluids (see for example, Homsy, G. M., "Viscous Fingering in Porous Media," Ann. Rev. Fluid Mech. **19** (1987), 271-311). Section 3 of Meakin describes numerical simulations of miscible displacement of a fluid by a second fluid with identical properties (page 2 paragraph 2), which implies that the two fluids have identical viscosities and mobilities. In contrast, the subject matter of the present application is a method for

simulating displacements in which the injected fluid is substantially less viscous than the resident oil (lines 10-14 on page 2 of the present application). Furthermore, Section 3 of Meakin uses a finite-difference numerical scheme and does not use any of the techniques of percolation theory. Even if the physical problems described by Meakin were relevant to adverse mobility displacement in a petroleum reservoir, Meakin derives results through the use of dynamic numerical simulation, presents those results only in the form of pictorial representations of fluid distributions, and provides no prescription for how those results might be reduced to analytic functions useful for representing fine-scale adverse mobility displacement behavior in coarse-grid reservoir simulation.

There would be no reason to find and read such an article in order to fix the dependency of the King approach on empirical correlations. And if by chance one did happen across the Meakin article, the brief mention of the use of a percolation model (a) is not be enabling, and (b) would not in any way suggest to a reader that use of percolation theory would through functional dependencies eliminate the need for empirical correlations that require fine-grid simulations to be accurate. There is nothing in Meakin to imply or suggest that percolation theory can be used "to provide fine-grid adverse mobility displacement behavior through functional dependencies." A key word search on *percolation* theory or model would result in many hits. Applicants do not contend otherwise. Applicants do contend that the use made of percolation theory in the present invention to solve the targeted deficiency of prior art methods is both novel and inventive.

Since the independent claims of the present application are not obvious, none of the claims are obvious, and Applicants respectfully request allowance of all claims, as amended herein.

If the Examiner wishes to discuss this application with counsel, please contact the undersigned.

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